Engineering Drawings

Front　　　Side　　　Back

Lenth: ±2mm
Width: ±2mm
Height: ±1mm
Row Pitch: ±2mm

A-A

Packaging Configuration

(Two pallets =One stack)

27pcs/pallet , 54pcs/stack, 594pcs/40'HQ Container

Electrical Performance & Temperature Dependence

Current-Voltage & Power-Voltage Curves (390W)

Temperature Dependence of Isc,Voc,Pmax

Mechanical Characteristics

Cell Type	Mono PERC 158.75×158.75mm
No.of Half-cells	144 (6×24)
Dimensions	2008×1002×40mm (79.06×39.45×1.57 inch)
Weight	22.5 kg (49.6 lbs)
Front Glass	3.2mm, Anti-Reflection Coating, High Transmission, Low Iron, Tempered Glass
Frame	Anodized Aluminium Alloy
Junction Box	IP67 Rated
Output Cables	TÜV 1x4.0mm², (+) 290mm, (-) 145mm or Customized Length
Connector	Jinko JK03M, Genuine MC4

SPECIFICATIONS

Module Type	JKM390M-72H-V		JKM395M-72H-V		JKM400M-72H-V		JKM405M-72H-V		JKM410M-72H-V		JKM415M-72H-V	
	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Maximum Power (Pmax)	390Wp	294Wp	395Wp	298Wp	400Wp	302Wp	405Wp	306Wp	410Wp	310Wp	415Wp	314Wp
Maximum Power Voltage (Vmp)	41.1V	39.1V	41.4V	39.3V	41.7V	39.6V	42.0V	39.8V	42.3V	40.0V	42.6V	40.2V
Maximum Power Current (Imp)	9.49A	7.54A	9.55A	7.60A	9.60A	7.66A	9.65A	7.72A	9.70A	7.76A	9.75A	7.81A
Open-circuit Voltage (Voc)	49.3V	48.0V	49.5V	48.2V	49.8V	48.5V	50.1V	48.7V	50.3V	48.9V	50.6V	49.1V
Short-circuit Current (Isc)	10.46A	8.02A	10.54A	8.09A	10.61A	8.16A	10.69A	8.22A	10.76A	8.26A	10.82A	8.31A
Module Efficiency STC (%)	19.38%		19.63%		19.88%		20.13%		20.38%		20.63%	
Operating Temperature (℃)	-40℃~+85℃											
Maximum System Voltage	1500VDC (IEC)											
Maximum Series Fuse Rating	20A											
Power Tolerance	0~+3%											
Temperature Coefficients of Pmax	-0.36%/℃											
Temperature Coefficients of Voc	-0.28%/℃											
Temperature Coefficients of Isc	0.048%/℃											
Nominal Operating Cell Temperature (NOCT)	45±2℃											

STC: Irradiance 1000W/m²　Cell Temperature 25°C　AM=1.5

NOCT: Irradiance 800W/m²　Ambient Temperature 20°C　AM=1.5　Wind Speed 1m/s

* Power measurement tolerance: ± 3%
  Voc tolerance: ± 3%
  Isc tolerance: ± 4%

The company reserves the final right for explanation on any of the information presented hereby. JKM395-415M-72H- V -A3C1-EN-ForAUSCEC

Appendix B

Materials Manufacturing CO₂ Emissions Literature

No. C 444
November 2019

Lithium-Ion Vehicle Battery Production

Status 2019 on Energy Use, CO_2 Emissions, Use of Metals, Products Environmental Footprint, and Recycling

Erik Emilsson, Lisbeth Dahllöf

ivl

In cooperation with the Swedish Energy Agency

ATTACHMENT CA/KIUC-IR-32
Page 15 of 26

Report C 444 – Lithium-Ion Vehicle Battery Production – Status 2019 on Energy Use, CO$_2$ Emissions, Use of Metals, Products Environmental Footprint, and Recycling

Summary

This report is an update of the previous report from 2017 by IVL: Life Cycle Energy Consumption and Greenhouse Gas Emissions from Lithium-Ion Batteries (C243). It has been financed by the Swedish Energy Agency.

A literature study on Life Cycle Assessments (LCAs) of lithium-ion batteries used in light-duty vehicles was done. The main question was the greenhouse gas (GHG) emissions from the production of the lithium-ion batteries for vehicles. A search for standardization of LCA methodology and new information regarding recycling, and information on the supply risks for important lithium-ion battery materials was also included in the literature study.

The data is presented as GHG emissions expressed as CO_2-equivalents, in relation to the batteries' storage capacity, expressed as kWh storage capacity. Based on the new and transparent data, an estimate of 61-106kg CO_2-eq/kWh battery capacity was calculated for the most common type, the NMC chemistry. The difference in the range depends mainly on varying the electricity mix for cell production. If less transparent data are included the maximum value is 146kg CO_2eq/kWh. The calculated range is substantially lower than the earlier 150-200kg CO_2-eq/kWh battery in the 2017 report. One important reason is that this report includes battery manufacturing with close-to 100 percent fossil free electricity in the range, which is not common yet, but likely will be in the future. The decrease in the higher end of the range is mainly due to new production data for cell production, including more realistic measurements of dry-room process energies for commercial-scale factories, and solvent-slurry evaporation estimates that are more in line with actual production. The former range also included emissions from recycling which was about 15kg CO_2-eq/kWh battery, which is not included in the new range.

Regarding standardization of LCA, Product Category Rules (PCRs) are published for their Product Environmental Footprint developed by the European Commission.

The average nickel-content is expected to increase and cobalt-content to decrease in newer batteries as the batteries that are produced are expected to move towards higher energy density and away from cobalt, which is at supply risk. The supply of nickel may in future also become at risk.

The PEF benchmark reports that twelve percent of the total GHG emissions for batteries is in the end of life stage in Europe.

There is still a need for more data, especially since the different production steps can be performed in different ways with different efficiencies. Also, data for electronics production still needs to become better. A standardized way for data collection is recommended, for example by using the Product Environmental Footprint Category Rules (PEFCR). Furthermore, more information on the metals supply chains is needed, as well as better traceability, so that sustainable production can be achieved and guaranteed.

SCIENCE ADVANCES | RESEARCH ARTICLE

ENGINEERING

Life cycle energy use and environmental implications of high-performance perovskite tandem solar cells

Xueyu Tian[1], Samuel D. Stranks[2,3], Fengqi You[1,4,5]*

A promising route to widespread deployment of photovoltaics is to harness inexpensive, highly-efficient tandems. We perform holistic life cycle assessments on the energy payback time, carbon footprint, and environmental impact scores for perovskite-silicon and perovskite-perovskite tandems benchmarked against state-of-the-art commercial silicon cells. The scalability of processing steps and materials in the manufacture and operation of tandems is considered. The resulting energy payback time and greenhouse gas emission factor of the all-perovskite tandem configuration are 0.35 years and 10.7 g CO_2-eq/kWh, respectively, compared to 1.52 years and 24.6 g CO_2-eq/kWh for the silicon benchmark. Prolonging the lifetime provides a strong technological lever for reducing the carbon footprint such that the perovskite-silicon tandem can outcompete the current benchmark on energy and environmental performance. Perovskite-perovskite tandems with flexible and lightweight form factors further improve the energy and environmental performance by around 6% and thus enhance the potential for large-scale, sustainable deployment.

INTRODUCTION

Industrial development and population growth have led to a surge in global energy consumption over recent decades. To address the increasing scarcity of fossil fuels, there are extensive research efforts focusing on sustainable and renewable energy substitutes. Among the wide array of renewable energy resources, abundant solar energy can be converted into electric power through photovoltaic (PV) technologies without inducing substantial environmental burden. To meet the stringent requirements of efficient deployment of PVs on a global scale, low manufacturing costs and enhanced power conversion efficiency (PCE) are urgently needed.

The emerging metal halide perovskite family has demonstrated great potential as light-harvesting active materials by virtue of excellent light absorption and charge-carrier mobilities (1). Despite record-breaking PCEs (up to 25.2%) (2), single-junction perovskite solar cells stand little chance to outcompete the current benchmark of crystalline silicon (PCE of 27.6%) that dominates the marketplace (2, 3). There are already several commercial (nonperovskite) multi-junction technologies including tandems and triple- and quadruple-junction modules that typically use III to V semiconductors, with promising PCEs that rival and even outperform the benchmark silicon PVs (4). Nevertheless, triple and quadruple junctions are prohibitively expensive for manufacture and terrestrial deployment (5) and thus, to date, are primarily implemented in space applications (6). Therefore, the best chance at large-scale deployment of PVs lies in cost-effective yet high-performance tandems. More encouragingly, perovskites can uniquely enable highly efficient tandems at low cost by integrating the merits of minimal thermalization loss in multi-junction configurations with the beneficial attributes of low-cost processing and high-throughput fabrication (7).

In the shorter term, hybrid perovskite-silicon tandems will pave the way toward widespread deployment of PVs by boosting silicon PVs at little additional cost (8). In the longer term, innovative tandem architectures such as perovskite-perovskite and perovskite–CIGS (copper indium gallium selenide) promise high-performance, inexpensive production of the entire system (4, 7, 9–11), and use in lightweight applications (7). Both of these silicon-free tandem architectures offer great opportunities to achieve moderate PCEs above 30% at reasonable cost and thus are garnering extensive interest in both industry and academia (4, 7, 9–13).

Most the of applied perovskite research is focusing on the enhancement of PCEs and long-term stability for single junctions or tandems (7, 9, 14–19). However, a critical gap in the literature is a critical assessment of the energy use and environmental implications throughout the life cycle of a module, which will be integral to the sustainable development of such innovative technologies (20). Previous life cycle assessment (LCA) studies on perovskite tandems investigated specific tandem stacks, but only considered limited impact categories (8, 21–23) because of the incomplete high-quality life cycle inventory (LCI) datasets in existing databases, and do not consider scalability and industry-compatibility issues. To the best of our knowledge, the existing works do not apply LCA tools to perovskite tandems while maximizing the important potential of scale-up.

Here, we directly assess the environmental impacts of two cutting-edge two-terminal (2T) monolithic perovskite tandem solar cells, namely, perovskite-silicon and perovskite-perovskite configurations (14, 17). First, we estimate their energy payback time (EPBT) and greenhouse gas (GHG) emission factor. In the environmental life cycle impact assessment (LCIA) of tandem PV electricity, the impact categories in the European product environmental footprint recommendation are adopted to unmask their full-spectrum environmental impacts at midpoint level (24). A total of 17 midpoint impact categories are considered with the focus on individual environmental issue. We note that the indicator associated with nuclear waste is not considered because of lack of data. Considering the immaturity of manufacturing techniques and the fluctuation of operating conditions, the energy and environmental performance of tandem solar cells are subject to uncertainty. Thus, a Monte Carlo simulation–based approach is adopted to decipher the uncertainty

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A

Primary energy consumption (MJ/m² module)

B

Carbon footprint (kg CO₂-eq/m² module)
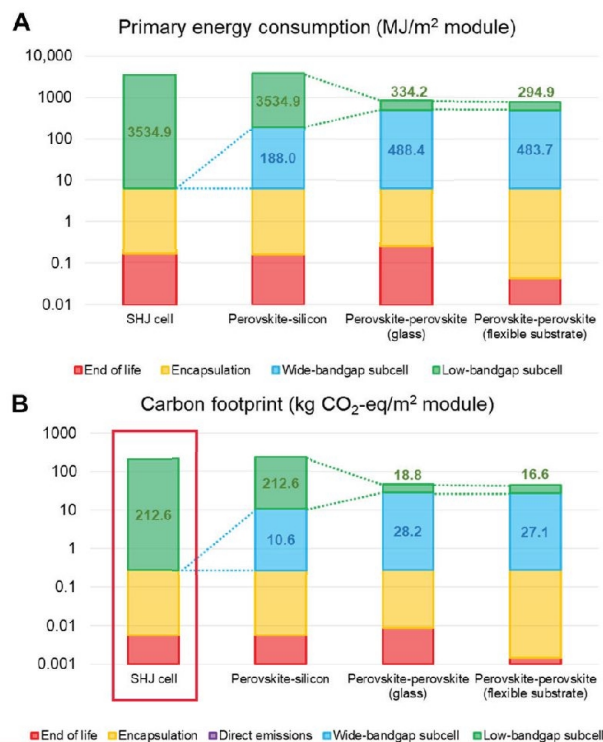
Fig. 2. Overview of primary energy consumption and carbon footprint for the SHJ cell, the perovskite-silicon tandem, and the perovskite-perovskite tandem (on both glass and flexible substrate) on a logarithmic scale. (**A**) Primary energy consumption breakdowns for the SHJ cell and the two tandem solar cells. (**B**) Carbon footprint breakdowns for the SHJ cell and the two tandem solar cells.

(23.1%) is lower than that of the perovskite-silicon tandem device (25.2%), the total primary energy consumption is only one-fifth of that of the perovskite-silicon tandem device. We note that despite the slightly lower PCE than perovskite-silicon tandems, perovskite-perovskite tandems, as well as perovskite-silicon tandems, will likely attain PCE exceeding 30% with continued improvement in selected materials and processing steps. More encouragingly, perovskite-perovskite tandem architecture demonstrates the capabilities for fabrication on flexible and lightweight substrate as well as large-volume manufacture, e.g., roll-to-roll processing. A resemblance can be observed between the profiles of primary energy consumption and carbon footprint. Notably, the end of life accounts for a lower proportion of the carbon footprint than the primary energy consumption for both perovskite-silicon and perovskite-perovskite tandems. In Fig. 2B, the contribution of the end of life for the flexible perovskite-perovskite tandem becomes even less substantial by virtue of lightweight form factors.

EPBT and GHG emission factor

On the basis of the primary energy consumption and carbon footprint results obtained in the previous section, we calculate the EPBT and GHG emission factor, two important metrics to measure the sustainability of PV technologies. To account for the uncertainty embedded in numerous key input parameters, including the performance ratio, PCE, annual irradiation, primary energy consumption, carbon footprint, and lifetime (46, 47), we adopt a Monte Carlo simulation–based method using the Oracle Crystal Ball (48). The performance ratio is defined as the ratio of actual to theoretically possible energy

output, which evaluates the quality of PV installation and accounts for all potential losses depending on the site, the technology, and the system scale. Notably, lifetime is the overarching influential factor on GHG emission factor, yet there is no reliable lifetime information for perovskite tandem cells in the literature. It is unlikely that widespread rooftop or utility-scale modules would be on the market with a lifetime less than 10 years (maintaining a reasonable performance), and this is also the lifetime value in which module replacement schemes become viable (33). To this end, a conservative lifetime of 15 years is assumed for both tandem devices with stable PCEs during their service life, whereas a 30-year lifetime is assigned to the benchmark silicon PVs, following the assumptions made in a previous tandem LCA study (20).

Figure 3A demonstrates the simulation results for both perovskite-silicon (blue cluster) and perovskite-perovskite (red cluster) tandem solar cells. We obtain an EPBT value of 0.35 ± 0.05 years and GHG emission factor of 10.94 ± 2.20 g CO_2-eq/kWh (mean ± SD) for perovskite-perovskite tandems. In contrast, the perovskite-silicon tandem device exhibits a longer EPBT (mean value, 1.46; SD, 0.23) by a factor of 4.2 and larger GHG emission factor (mean value, 47.46; SD, 10.08) by a factor of 4.3. Here, we refer back to the benchmark silicon PVs (SHJ cell with a PCE of 22.6%), which has an EPBT of 1.52 years and a GHG emission factor of 24.63 g CO_2-eq/kWh. The large gap between the GHG emission factor of perovskite-silicon tandem and the SHJ cell is attributed to the critical difference in lifetime. This, in turn, puts emphasis on the requirement to prolong the lifetime to reduce the climate impact of emerging tandem technologies. To verify the estimates with respect to EPBT and GHG emission factor, we present a detailed comparison against the results from existing literature on tandem LCA in fig. S3.

Moreover, sensitivity analyses are performed according to the simulation results, as shown in Fig. 4 (A to D). The nominal value for the performance ratio is set to the default value of 0.75 according to Frischknecht et al. (24). The electric-to-primary energy conversion coefficient is determined as per the Western Electricity Coordinating Council (WECC) electricity mix according to the Ecoinvent database (49). The same distributions are assigned to the key input parameters according to Gong (36), which are shown in the right-hand-side labels in Fig. 4 (A to D) in terms of mean and (geometric) SD. The minus signs indicate the corresponding input parameters that are in negative correlation with the objective function value and vice versa. The absolute values of percentages inform what fraction each parameter can influence the calculated quantity. The deviation of EPBT from its nominal value is induced by the fluctuations in the performance ratio, the respective primary energy consumption of each subcell, the overall PCE, and the annual insolation. An additional factor, the lifetime, leads to notable variation in the GHG emission factor. The performance ratio can be intuitively identified as the dominant factor among the mutual input parameters that exert influence on both sustainability metrics. The impact of the module efficiency and insolation is much less pronounced. The contributions to these metrics from the low- and wide-bandgap subcells are similar for the perovskite-perovskite tandem, whereas the bottom cell presents substantially higher impacts in the perovskite-silicon tandem architecture due to the large difference in these metrics between the SHJ cell and perovskite solar cell. Other factors, such as device degradation (beyond imposing a limited lifetime of 15 years), that may affect the energy yield are not considered in this work but should be carefully addressed in future work.

Appendix C

Detailed CO₂ Emissions Calculations

West Kaua'i Energy Project
Construction Phase Emissions Analysis

Activity	Unit	Quantity	Total Hours	CO2 Emissions (metric tons)
Construction Equipment Operation *				
Air Compressor (gasoline)	ea	1.00	1,690	29.268
Backhoe w/ Hoepack (diesel)	ea	1.00	1,819	36.883
Dozer-D6 (diesel)	ea	2.00	3,672	117.865
Dozer-D8 (diesel)	ea	2.00	8,607	276.271
CAT 336 Excavator (diesel)	ea	3.00	7,968	260.644
CAT 349 Excavator (diesel)	ea	3.00	7,360	240.755
CAT 352 Excavator (diesel)	ea	3.00	13,172	430.873
CAT-Grader (diesel)	ea	1.00	689	24.927
CAT 950 Loader (diesel)	ea	1.00	3,892	112.658
CAT 966 Loader (diesel)	ea	1.00	813	23.533
CAT 980 Loader (diesel)	ea	2.00	9,934	287.550
CAT 272 Skid Steer (diesel)	ea	1.00	4,245	34.970
CAT 735 Off-Road Dump Truck (diesel)	ea	5.00	25,239	2,352.486
CAT 815F Roller (diesel)	ea	2.00	6,141	112.013
CAT 825G Roller (diesel)	ea	1.00	1,515	27.634
Vibrating Roller 48" (diesel)	ea	1.00	2,262	41.259
Vibrating Roller 84" (diesel)	ea	1.00	1,526	27.835
400 amp Welder (Diesel)	ea	3.00	17,413	162.072
Water Truck 2000 Gal (diesel)	ea	2.00	8,356	778.849
Water Truck 4000 Gal (diesel)	ea	1.00	4,317	402.381
			Total	*5,780.726*
Transportation Equipment Operation * **				
F-150 Truck (gasoline)	ea	1.00	6,570	8.574
F-250 Truck (diesel)	ea	4.00	6,570	33.790
F-350 Truck (diesel)	ea	4.00	6,570	33.790
F-550 Truck (diesel)	ea	4.00	6,570	33.790
Semi-Truck (diesel)	ea	3.00	6,570	32.522
			Total	*142.466*
**Construction Materials Manufacturing ** **				
Portland Cement Type 1	ton	600.00		504.600
Coating Systems Primer Carboline 859	gal	300.00		-
Coating Systems Intermediate Carboline 888	gal	200.00		-
Granular Material Cl II Tri City	cu.yd.	900.00		0.090
Sand Class II(d) for Underlain	cu.yd.	3,200.00		0.320
Fine Aggregate 2FA	ton	10,000.00		61.578
Fence Post Steel Woven Wire	ea	100.00		7.223
Fence Chain Link	ft	2,000.00		18.490
Fence Post Steel Woven Wire	ea	200.00		14.446
Fence Gate Chain Link	lbs	10.00		-
Fence Chain Link	ft	10,000.00		92.452
Fence Post Steel Woven Wire	ea	1,000.00		72.228
Curing Compound Clear	gal	200.00		2.511
Concrete	cu.yd.	10,000.00		2,082.805
Rip Rap Plain	sq.yd.	600.00		11.005
Pipe Steel	ft	34,800.00		5,095.141
Pipe Underlain	ft	1,000.00		0.424
Concrete Surface Coating	gal	200.00		2.511
Geotextile Liner	sq.yd.	29,000.00		37.659
Steel Reinforcement	lbs	415,000.00		107.439
Solar Batteries *****	kWh	70,000.00		7,420.000
Solar PV Panels ******	sq.m.	271,500.95		57,721.103
			Total	*73,252.025*
			TOTAL	**79,175.217**

ASSUMPTIONS

1 - Construction Equipment Operation

1.a - 18-month construction period, 50 working weeks per year, 5 days per week, 8 hours per day

1.b - Construction equipment would operate at maximum power during operation

2 - Transportation Equipment Operation

2.a - 18-month construction period, 50 working weeks, 5 days per week

2.b - 30 full time construction workers, 3 owner staff, all workers/staff travel in separate vehicles

2.c - Construction transportation considers workers traveling from their lodging location to the project site and back daily. Round trip average mileage 40 miles per day per worker, 17 miles per gallon fuel efficiency

3 - Construction Materials Manufacturing

3.a - Major materials consumption including concrete, steel, and aggregates were estimated to determine the anticipated consumed materials consumption.

REFERENCES

* https://www.construction.mtu.edu/cass_reports/webpage/equip_estimator.php
** https://www.construction.mtu.edu/cass_reports/webpage/mat_estimator.php
*** https://www.sbeap.org/air-quality/tools/pte-calc
**** https://www.ivl.se/download/18.14d7b12e16e3c5c36271070/1574923989017/C444.pdf
***** https://advances.sciencemag.org/content/6/31/eabb0055/tab-pdf

West Kauaʻi Energy Project
Operation Phase Emissions Analysis

Activity	Unit	Quantity	Total Hours	CO2 Emissions (metric tons)
Construction Equipment Operation *				
Air Compressor (gasoline)	ea	1.00	416	7.204
Backhoe w/ Hoepack (diesel)	ea	1.00	260	5.272
CAT 336 Excavator (diesel)	ea	1.00	260	8.505
CAT 950 Front End Loader (diesel)	ea	1.00	260	7.526
CAT 272 Skidsteer (diesel)	ea	1.00	416	3.427
400 amp Welder (diesel)	ea	1.00	260	2.420
Water Truck 2000 Gal (diesel)	ea	1.00	130	12.117
			Total	46.471
Transportation Equipment Operation **				
F-250 Truck (diesel)	ea	2.00	468	1.200
F-550 Truck (diesel)	ea	1.00	260	0.330
Semi-Truck (diesel)	ea	1.00	468	0.772
			Total	2.302
Construction Materials Manufacturing				
			TOTAL	48.773

ASSUMPTIONS

1 - Construction Equipment Operation

1.a - Construction equipment would only be used for O&M activities

2 - Transportation Equipment Operation

2.a - Transportation equipment would only be used for O&M activities

3 - Construction Materials Manufacturing

3.a - No construction materials would be used for operation

REFERENCES

* https://www.construction.mtu.edu/cass_reports/webpage/equip_estimator.php
** https://www.sbeap.org/air-quality/tools/pte-calc

West Kauaʻi Energy Project
Decommissioning Phase Emissions Analysis

Activity	Unit	Quantity	Total Hours	CO2 Emissions (metric tons)
Construction Equipment Operation *				
Air Compressor (gasoline)	ea	1	1,524	26.393
Backhoe w/ Hoepack (diesel)	ea	1	520	10.544
CAT 336 Excavator (diesel)	ea	1	1,558	50.951
CAT 352 Excavator (diesel)	ea	1	1,492	48.792
CAT 950 Front End Loader (diesel)	ea	1	1,294	37.445
CAT 272 Skidsteer (diesel)	ea	2	1,676	13.810
400 amp Welder (diesel)	ea	2	520	4.840
Water Truck 2000 Gal (diesel)	ea	1	1,524	142.050
			Total	*334.824*
Transportation Equipment Operation **				
F-250 Truck (diesel)	ea	3	3,285	12.670
Semi-Truck (diesel)	ea	3	3,285	16.260
			Total	*28.930*
Construction Materials Manufacturing				
			TOTAL	**363.754**

ASSUMPTIONS

1 - Construction Equipment Operation

1.a - 45 working weeks, 5 days per week, 8 hours per day

1.b - Construction equipment would operate at maximum power during operation

2 - Transportation Equipment Operation

1.a - 45 working weeks, 5 days per week, 8 hours per day

2.b - 8 full time construction workers, 1 owner staff

2.c - Construction transportation considers workers traveling from their lodging location to the project site and back daily. Round trip average mileage 40 miles per day per worker, 17 miles per gallon fuel efficiency

3 - Construction Materials Manufacturing

3.a - No construction materials would be used for decommissioning

REFERENCES

* https://www.construction.mtu.edu/cass_reports/webpage/equip_estimator.php

** https://www.sbeap.org/air-quality/tools/pte-calc

West Kauaʻi Energy Project
Solar Battery CO2 Manufacturing Emissions

Product:	Lithium Ion Samsung E3-M088	
Project Size:	35,000	(kW)
Storage Time:	2	(hours)
Energy Storage:	70,000	(kWh)

	#	Unit
CO2 Manufacturing Emissions	106.000	kg/kWh
CO2 Emissions	7,420,000.000	kg
CO2 Emissions	**7,420.000**	**metric tons**

West Kauaʻi Energy Project
Solar PV Panel CO2 Manufacturing Emissions

JinkoSolar Product #:	JKM415M-72HL-V	
Panel Area (2.008m x 1.002m):	2.012016	(square meters)
Project Size:	56,000	(kW)
Panel Size:	0.415	(kW)
Panels:	134,940	(#)
Panels:	271,501	(square meters)

	#	Unit
CO2 Manufacturing Emissions	212.600	kg/square meter
CO2 Emissions	57,721,102.867	kg
CO2 Emissions	**57,721.103**	**metric tons**

Appendix D

Response to Comments

1.0   Response to Comments

1. Please confirm that the estimates provided in Table 2-1 only include the PV/BESS portion of the WKEP.

   RESPONSE: The estimates provided in Table 2-1 include all phases and components associated with both the PV/BESS and PSH/Hydropower project: Construction, Operation, and Decommissioning. The PV/BESS portion is included in the table under "Construction / Construction Materials Manufacturing". Please refer to the last two pages in Appendix C "Solar Battery CO_2 Manufacturing Emissions" and "Solar PV Panel CO_2 Manufacturing Emissions" for itemized CO_2 emissions calculations.

2. Please discuss the GHG emissions (by activity) that would be associated with the PSH and hydropower-only portions of the WKEP. Please provide supporting evidence KIUC's assertion that emissions from these portions of the WKEP are minimal, such that almost all of the emissions are attributable to the PV/BESS component.

   RESPONSE: Appendix C has broken out all activities associated with the project. The PV/BESS component consists of 65,141.103 metric tons of CO_2 emissions (82%) in the construction phase from material production which is not expected to occur in the State of Hawaii. Excluding the PV/BESS component, the construction phase would result in 14,236.81 metric tons of CO_2 emissions (18%) from the PSH/Hydropower component. Operation and decommissioning activities would not change as they do not have a PV/BESS component.

3. Please provide all tables in Appendix C in native format with all formulas intact. To the extent not already provided, please also provide all supporting materials or documentation used in producing Appendix C, in their native formats with any formulas intact. As Appendix C includes links to more than one CO2 emission estimators/calculators, please specify which estimator/calculator was used for which part of the emission analysis and document why the particular estimator/calculator was selected.

   RESPONSE: The native Microsoft Excel spreadsheets have been included with the revised final submittal. References have been added to the Microsoft Excel spreadsheet and updated in the appendices. The following documents the reasons for using the each respective estimator/calculator to determine CO_2 emissions.

   - *The PE-2 Project Emission Estimator for Equipment was used for all off-road equipment to construct, operate, and decommission the project. The available list of equipment is extremely comprehensive and covered all equipment anticipated to be utilized. The results of this estimator are automatically generated from the website and were copied and pasted into the Appendix C spreadsheet. The hours input into the estimator were estimated by the McMillen Jacobs Associates construction estimating team.*

   - *The PE-2 Project Emission Estimator for Materials was used for materials to construct the project. The available list of materials is extremely comprehensive and covered all materials anticipated to be utilized. The results of this estimator are automatically generated from the website and were copied and pasted into the Appendix C spreadsheet. The quantities input into the estimator were estimated by the McMillen Jacobs Associates construction estimating team.*

- *The Engine Potential to Emit (PTE) Spreadsheet was used for on-road equipment as it included on-road vehicles that would be used to construct, operate, and decommission the project. The native spreadsheet has been included with the revised final submittal. During the review of this spreadsheet, an error was observed and corrected in the spreadsheet along with the revised final report and appendices.*

4. Appendix B includes an article on lithium-ion vehicle battery production, and Appendix C shows detailed CO2 emissions calculations. To the extent not previously addressed, please clarify specifically how the Lithium-Ion Vehicle Battery Production report is being used to support the GHG analysis.

    RESPONSE: There are no reports available specifically for production emissions of the proposed battery system. However, the production of Lithium-Ion Vehicle Batteries is similar to the production of the solar batteries proposed for the project. This industry standard data was used for determining GHG emissions as the production of vehicle batteries for the same size of project (35,000 kW) with a storage time of 2 hours would be the same since the end result is the size of energy storage using a very similar technology.

5. Please explain how the range of 61-106kg CO2 eq/kWh battery capacity is used in the detailed CO2 emissions calculations. Please describe why the point estimate used is the best and most appropriate estimate given the characteristics of the proposed Project.

    RESPONSE: The high estimate was used for the CO_2 emissions calculations due to the variability of where the batteries would be produced. Different countries have varying standards for GHG regulations in regards to the production of the battery as well as the energy source used to created the battery. Pending on where the batteries are produced can result in a range of emissions. In order to not underestimate the potential CO_2 emissions, the high value in the range was selected for this analysis.

6. For each vehicle described in the analysis, please indicate the type of fuel used (e.g., gasoline, electricity, etc.), the assumptions regarding the emissions associated with the use of that fuel, and how the CO2 emissions were calculated. Please include all supporting assumptions, references, calculations, workpapers, and native files with all formulas intact.

    RESPONSE: The spreadsheet has been updated with the type of fuel used. The native spreadsheet has been included with the revised final submittal.

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CA/KIUC-IR-33   Ref: Application, pages 21-22, Exhibit 5, Appendix C.

McMillen Jacobs Associates estimates about 80,000 metric tons of CO_2 would be emitted during the construction of the Project and the decommissioning of the PV/BESS Facility.

a.   Please discuss the end of life decommissioning plans and land restoration plans for both PV/BESS Facility and other components of this project.

RESPONSE: As a clarification, the McMillen Jacobs Associates estimate of about 80,000 metric tons of CO2e that would be emitted includes the construction, operation, and decommissioning of the Project for the PV/BESS, PSH and Hydropower-only components of the Project (i.e., not only construction of the Project and the decommissioning of the PV/BESS Facility). At the end of the Project life, all PV/BESS, turbine, pump and major electrical equipment will be repurposed or recycled to the extent required and possible, or disposed of in accordance with the applicable regulation(s) in effect at the time of disposal. AES intends to develop an end-of-life management plan for the Project equipment during the contract term when end-of-life programs have been defined.

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Land restoration plans will depend upon any requirements contained within the final land use agreements. KIUC expects that the requirements will include removal of all equipment or, if left in place, the equipment would become the property of the landowner.

b. To the extent not previously addressed, please list materials and equipment that needs to be removed from the project site.

RESPONSE: At this time, KIUC does not know what specific materials and equipment that it will need or be required to remove from the Project site, although KIUC would plan to repurpose or recycle all PV/BESS, turbine, pump and major electrical equipment to the extent required and possible, or dispose of them in accordance with the applicable regulation(s) in effect at the time of disposal. The specific requirements of what KIUC will be required to remove from the Project site will be in large part dictated by the end-of-life management plan to be developed by AES for the Project equipment when end-of-life programs have been defined and/or by the terms of the final land use agreements.

c. Please discuss how land classification and zoning contributed to the KIUC's determination that decommissioning and

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disposal of any of the above listed equipment and infrastructure is not necessary.

RESPONSE: Not applicable. KIUC has not made any determination that decommissioning and disposal of any Project equipment and infrastructure is not necessary.

d. Please discuss how these restoration costs have been imputed into the cost of the project.

RESPONSE: The cost of restoration and decommissioning of the Project is included in the Project cost, and is the sole responsibility of AES.

e. Please discuss in detail the land management plan and baseline upon which AES and KIUC will determine whether the land was successfully restored to its condition prior to construction. Please provide an electronic copy of this plan and the proposed methodology that will be used to conduct a baseline analysis.

RESPONSE: A land management plan and baseline upon which AES and KIUC will determine whether the land was successfully restored has not yet been developed. The completion of project development, all environmental studies, land use agreements, and the permitting process will inform the

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detailed decommissioning plan and how AES and KIUC can

develop a methodology for determining whether the land was

successfully restored to its required condition.

SPONSOR: Brad Rockwell

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CA/KIUC-IR-34   Ref: Application, pages 20-21.

KIUC states that the Project "will not be subject to variable fuel pricing and the resulting rate instability that can occur with fossil fuel fired generation" and that, once the Project is placed into service, KIUC will use approximately 212 million gallons less fuel over the term of the PPA, saving KIUC's members/customers between $157 and $172 million.

a.   Please provide any supporting documentation or analysis indicating the extent to which the proposed Project is expected to reduce the rate instability that can occur with fossil fuel fired generation.

RESPONSE: The Project will provide energy to KIUC at a fixed rate that is not tied to the price of oil or any other variable index (such as the Honolulu Consumer Price Index). This not only eliminates variable pricing that causes electric rate instability, but also acts as a downward price trend after considering inflation. Without the proposed Project, KIUC would need to (at least in the near term) continue to produce the energy that would otherwise be served by WKEP using fossil fuel fired generation, which uses highly refined oil products, like ultra-low sulfur diesel and naphtha. The prices of these fuels

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                are tied to overseas market indexes that are affected by both local and global events, and the prices change each month according to the market indexes. As such, continuing to use fossil fuel will undoubtedly result in more rate instability than using the renewable energy produced from WKEP under the terms of the subject PPA.

b.   Please clarify whether the $157 to $172 million savings referenced above represents KIUC's estimate of the reduction in funds necessary for fuel imports if the proposed Project is brought online. Please provide the calculations and workpapers that support this response.

RESPONSE: The savings referenced above represent KIUC's estimate of the net present value of the 25-year annual savings resulting from the cost of energy from WKEP versus the cost of the same energy from oil-fired generating units. See also the response to CA/KIUC-IR-16, part a. and Attachment CA/KIUC-IR-16a.

c.   Please discuss how the Project will affect the State's fuel supply reliability risk. Provide all calculations and workpapers to support your response.

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RESPONSE: As noted on page 21 of the subject Application (and referred to by the Consumer Advocate in its information request above), the Project is expected to result in approximately 212 million gallons less fuel being used over the initial 25-year term of the PPA. This will significantly reduce KIUC's and Kauai's fuel supply reliability risk, and in turn, help to reduce the State's overall fuel supply reliability risk.

SPONSOR: Brad Rockwell

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CA/KIUC-IR-35   Ref: Application, page 27; Exhibit 6, page 10.

Table 3-1 lists material and labor costs associated with the transmission line, contractor costs for the fiber, engineering, survey, and contingency. The total cost is $2.7 million. On page 27 of the Application, KIUC states its "preliminary estimate of the costs it will incur to perform the work is at least $2.7 million."

a.   Please discuss the reasonableness of the New Overhead Circuit and Conductor work cost in total and by each line item. Please include in the discussion, comparisons of the various cost components in past projects.

RESPONSE: The New Overhead Circuit and Conductor Work design is based on standard hardware to the maximum extent possible. KIUC is familiar with these standard costs. These standard materials include pole anchors, anchor rods, 559.5 AAAC 'Darien' conductor, crossarms, insulators, ground rods, and composite poles. All hardware will be utility-grade to withstand the elements for this location. Each hardware component has a labor rate to install. Non-standard hardware is based on prior costs on other projects - an example of this is the contracted fiber optic cable materials and labor to install. When broken down on a per foot basis, this subject work is

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comparable to prior projects and work performed by KIUC. Other costs involved are engineering, surveying, and contingency. These costs utilize percentages that are based on KIUC's prior project experience.

b. Given that the cost estimate reflects "contingency", please discuss why KIUC states the cost estimate for the New Overhead and Conductor work is <u>at least</u> $2.7 million. That is, what other factors, beyond those considered in "contingency" costs, might drive the costs higher than $2.7 million.

RESPONSE: The cost estimate is based on KIUC's preliminary engineering for the New Overhead Circuit and Conductor Work. Contractor labor for digging is invoiced based on a time and material basis since the contractor will not be able to foresee what delays could be incurred while digging. Additionally, contractor work for fiber is an estimate as a result of prior contracts. KIUC will not know the true cost until bids are received. Other unforeseen costs could also arise due to factors such as an increase in material demands across the nation for similar components, an unexpected shortage in such components, and various unknown conditions that may be experienced while the subject work is being performed, all

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of which could drive up the cost of the work. Additionally, the budgeted amount is based on the network upgrades terminating at the WKEP Substation location at Substation Alternative 1 as discussed in the response to CA/KIUC-IR-5, part a. If Substation Alternative 2 is instead chosen for the substation location, costs would be impacted as this would involve additional engineering, surveying, materials and labor to complete this portion of the Project.

SPONSOR: Cameron Kruse

The table below identifies redacted confidential information contained in KIUC's Responses to the Division of Consumer Advocacy's First Submission of Information Requests that is being submitted as CONFIDENTIAL pursuant and subject to Protective Order No. 37605, issued on February 4, 2021 in Docket No. 2020-0218. The following table: (1) identifies, in reasonable detail, the confidential information's source, character, and location of the confidential information; (2) states clearly the basis for the claim of confidentiality; and (3) describes, with particularity, the cognizable harm to the producing party from any misuse or unpermitted disclosure of the information.

Reference	Identification of Item	Basis of Confidentiality	Harm
Confidential Attachment CA/KIUC-IR-11a (Part 2)	Confidential Attachment CA/KIUC-IR-11a (Part 2) contains the model prepared by one of KIUC's consultants and used by KIUC to check the reasonableness of the proposed PPA pricing by modeling the PV/BESS[1] component of the Project on a stand-alone basis using the data and assumptions from KIUC's internal project cost modeling.	The attachment contains confidential business, commercial, and financial information and/or other information considered confidential, privileged, proprietary and/or subject to non-disclosure pursuant to and in accordance with certain laws, rules, regulations, directives or agreements. This information is highly sensitive in nature, is being held in confidence by KIUC, and has not been provided or otherwise disclosed to the public. This information is protected from public disclosure, pursuant to the "frustration of legitimate government function" exception of the Uniform Information Practices Act ("UIPA"). See footnote of the cover pleading to which this Attachment 1 is attached for a further discussion of the frustration of legitimate government function exception.	Any misuse or unpermitted disclosure would disadvantage or harm KIUC by disclosing directly or indirectly, information regarding KIUC's businesses, commercial or financial matters deemed confidential, privileged or proprietary and/or subject to non-disclosure under certain laws, regulations, directives or agreements, thus infringing upon certain privacy and proprietary rights, and/or exposing KIUC or others to undue harm, unfair competitive disadvantage or to certain liabilities. For example, such misuse or unpermitted disclosure could place KIUC at a disadvantage by providing information and insights regarding KIUC's confidential business operations, practices and decisions that they would not otherwise be able to obtain and that could be used for unfair advantages or reasons.

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[1]   Capitalized terms used, but not otherwise defined herein, shall have the same meanings ascribed to such terms in the subject Application filed in this docket on December 31, 2020.

190229.4

Reference	Identification of Item	Basis of Confidentiality	Harm
Portions of (1) Attachment CA/KIUC-IR-24a (Part 1) and (2) Attachment CA/KIUC-IR-24a (Part 3)	The redacted portions of Attachment CA/KIUC-IR-24a (Part 1) and Attachment CA/KIUC-IR-24a (Part 3) contain entity and/or individual identifying information from KIUC's various community and public outreach efforts.	KIUC does not have the consent of the redacted entities and individuals to disclose their respective identify as part of the subject filing. As such, the redacted information contains confidential personal information that, if disclosed, could constitute an unwarranted invasion of personal privacy, which is protected from public disclosure, pursuant to the "privacy exception" of the UIPA. See footnote of the cover pleading to which this Attachment 1 is attached for a further discussion of the privacy exception.	Public disclosure of this information could constitute an invasion of personal privacy and expose the person(s) to, among other things, potential victimization, and potentially expose KIUC to potential liabilities, as well as the cost of addressing any potential untoward uses of the confidential information and could also harm KIUC's relationships with the redacted entities and/or individuals.

190229.4

CERTIFICATE OF SERVICE

I hereby certify that on this date a copy of the foregoing document was duly served upon the following party and participants electronically to the email addresses shown below pursuant to HAR § 16-601-21(d), as modified by Order No. 37043 Setting Forth Public Utilities Commission Emergency Filing and Service Procedures Related to COVID-19, filed on March 13, 2020.

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DATED: Honolulu, Hawaii, May 12, 2021.

/s/ Jamie C. Yoshikane
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